Investigating of Electroless Nickel Plating Process for Polypropylene Nonwoven Fabric

V. Ramesh Babu, Ariharashudan, Chandrasekaran, A. Arunraj

Abstract: Metalized fabric substances have a large capacity in the various scope of applications which include electromagnetic field defensive, infrared radiation safety, obtaining fabric substances with antistatic, antibacterial, electrically conductive, radio soaking up, heat reflective and other unique houses. The aim of our project work is to develop a metallized textile through Electro less Nickel Plating Technique and to optimize the process parameters to get high nickel deposition on spun bond polypropylene nonwoven fabric through Box and Behnken method. It was found that the optimum deposition taken place when the process conditions were kept at Temperature (°C) = 60, Time = 30 min and pH= 9. The SEM analysis reveal that uniform coating and existence of nickel on the surface of the substrate produced from the above optimum conditions. The concert of nickel-finished nonwoven fabric spun bond polypropylene become determined to be depending on the quantity of nickel debris adhered on the material substrate. The optimized spun bond polypropylene nickel-plated nonwoven fabric was greater in their thermal properties and color fastness to light and washing. However, there was a decrease in rubbing fastness.

Keywords: nickel plating, nonwoven, fabric, polypropylene, textile

I. INTRODUCTION

In latest years, 4 types of metallized processing technology were implemented to textiles: i. electroless plating, ii electroplating, iii. ion plating and iv. vacuum deposition. Among the four techniques the electroless plaiting is simple and cost effective method.1 Electroless plating additionally referred non-galvanic form of plating, electroless plating is an automobile-catalytic plating or, chemical the method that includes numerous simultaneous chemical reactions in an aqueous media occurring without the use of outside electric current.2 Ion change plating is used for tin plating of copper and aluminum whilst autocatalytic plating is in most cases applied to nickel, copper and alloys. The 88-99% of nickel and the remaining with, boron, phosphorous, or a few additional likely components constitutes electroless nickel plaiting. A popular technique of covering non-conductive substrates with nickel without the participation of power is known as electroless nickel plating .3 The exceptional traits of electroless nickel (EN) coatings consist of their capability to be implemented to a selection of substrate materials including metals (conductive) and non-metallic (non-conductive) substances and their capacity to the plate uniformly on geometrically tricky components because noexternal power is applied to the element consequently, this method is referred to as electroless. During the chemical reaction the reducing agent is released by hydrogen, and oxidized sodium hypophosphite to provide a negative ion on the surface of the substrate. New strategies are employed to place metals on sample planes for appealing or protecting purposes. Although metallized treatment era is novel to the fabric design arena, it has an ability for value addition in clothing for functional and ornamental values.1

Electroless nickel coating on textile substances offers features like electrical conductivity, anti-static and wonderful ornamental effect.These extensive range of scientific solutions, electroless nickel coating has splendid ability in clothing businesses. 5 Electroless nickel plaiting, consequently be able to be custom-made to encounter the detailed desires of an request with the appropriate assortment of the nickel's alloying element(s) and their corresponding percentages in the plaited sheet.6 Knowledge shows that each substrate needs its own precise methods; depositing active metal onto the surface of a non (semi)conductor is still to a certain extent an art. Enormous paintings has been achieved to symbolize binary electroless Ni–P alloy deposits on metals, at the same time as the gadget on non-metals has been studied to a miles lesser extent.4 In previous work the electroless nickel-phosphorus (Ni-P) coating on a non-metallic cloth polypropylene sheets evaluated by the use of sodium hypophosphite as a decreasing agent in alkaline media.7 In another investigation, the chance of making use of the electroless nickel coating in cloth design was discovered.8 Electroless Nickel coating Method for polyester cloths were carried out to optimize the process conditions.9Optimization of the efficacy of the nickel element deposition on cloth is essential, in order to apply this method to manufacturing use properly. Optimized electroless nickel coating technique can deliver beneficial evidence for the manufacturing to get a more superiority and constant plating. Hence in this research work the technical limitations such as pH, temperature and period in nickel deposition on spun bond polypropylene nonwoven fabrics are analyzed through box and behnken method to make the most of the amount of nickel elements on the cloth surface.

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II. MATERIALS AND METHODS

A. Fabric

The Textile material chosen for the Optimization of Electroless nickel coating process is 100% Spun Bond Polypropylene Nonwoven with white colour which was sourced at commercial market.

The GSM of the fabric is 140. The material used for the plating process is in the dimension of 16cm X 16cm.

B. Chemicals

The Chemicals required to carry out the Electroless Nickel Plating Process are Palladium chloride (PdCl2), Hydrochloric acid (HCl), Sodium citrate (Na3C6H5O7•2H2O), Stannous chloride (SnCl2•H2O), Nickel(II) sulphateHexahydrate (NiSO4•6H2O), Sodium hypophosphite (NaH2PO2•H2O), Boric acid (H3BO3) and Deionised Water. In the electroless nickel coating method chemicals used are AR mark.

C. Method

Electroless Nickel plating is wholly carried out by chemical processing where there is no requirement for electric current to plate a metal onto a substrate and the plating can be done within 1000°C in the laboratory by using conventional equipment's used for chemical processing. Pre-cleaning, Sensitisation, Activation, Electroless Nickel Deposition and Pre-treatment process are the five main stage of electroless nickel plaiting.

D. Pre-cleaning

In this process, all the fabric samples treated with 2% non-ionic soap at pH 7 and temperature 40˚C for 20 min. De-ionised water was used to rinse the pre-cleaned samples. Before carrying out the nickel plating process the additives and/or contaminants should be removed because they have profound effect on performance.

E. Sensitisation

The washed fabric samples were exposed to the mixture of 10gram/l stannous chloride and 40ml/litre HCL {conc. 37%} (surface sensitizer) at 25˚C for 10min at pH 1. In Sensitisation, non-conductive samples absorb the stannous Sn2+ ions from the stannous solution. For the deposition of nickel this enables the fabric surface to act as a catalyst.

F. Activation

The sensitised fabrics were washed with deionised water successively and then dipped in the activator solution (mixture of Chloride and 20ml/l Hydrochloric acid (conc. 37%),0.2g/l Palladium (II) at pH 2 and 25˚C for 10 min in order to attain external activation. Subsequently the activated fabrics were rinsed with de-ionised water. Activation is carried out for activating the fabric surface for nickel deposition. In activation, acid palladium chloride solution i.e. nucleate solution where the sensitised substrate transports the stannous (Sn2+) and counters with palladium (Pd2+) ions to perform nucleation effect on the sensitised substrate. The sensitised tin on the substrate surface reacts with palladium salt in the activation solution to eliminate divalent tin on the substrate surface.

Deposition: In this deposition sodium hypophosphite monohydrate is used as reducing agent. The nickel electroplating solution, was active in the Electroless nickel coating tank, which was composed of sulphate, 20gram/l sodium citrate, 20gram/l nickel (II) 20gram/l sodium hypophosphite and 20g/l boric acid during the deposition phase. Deposition includes reducing the nickel salt into nickel, i.e. the reducing agent reduces metal ions as metals. The temperature, time and pH are the crucial factors in deposition of nickel particles on substrate which has to optimized.

G. Optimization of Deposition

The result of metal deposition is relatively crucial which is affected in electroless nickel deposition stage. Once the cloth surface becomes triggered, the deposition phase is the single feature prompting the metallic bond efficacy. With the intention to maximise the quantity of nickel debris adhered on the fabric, the optimisation of the deposition circumstance of electroless nickel plating is to be carried out.

Process parameter	Different levels		
	-1	0	+1
Temperature. (X_1)	40° C	60° C	80° C
Time. (X_2)	15min	30min	45min
pH.(X_3)	8	9	10

Table.1 Parameters for Optimising Nickel Plating Process

H. Statistical analysis andoptimization process

To determine the influence of time, temperature and pH an experimental plan was designed and processed according to a central composite design, proposed by using Box-Benhken method. In this experimental plan, three levels and their three variables were selected i.e., the variables were used for the nickel electroplating solution arrangement in the deposition method. (Table.1).The 16x16 inch samples are treated in above conditions with continuous stirring for electroplating reaction (Yuen et al., 2006a, 2007).

Second order quadratic polynomial equations were formulated for composite property in terms of independent variables, using statistical software package MiniTab version 15. Generalized equation is as follows.

$$Y = b_{0} + \sum b_{i} X_i + \sum b_{ii} X_i^2 + \sum b_{ij} X_i X_j \qquad (1)$$

where b0, bi, bii, and bij are the co-efficient of the regression equation, i, j, are integers with i > j, and Y, the response or dependent variable (composite property).

Contour plots were plotted for each response with 2 independent variables at a time and maintaining third variable at constant level using Minitab software version 15.

Post-treatment: Post-treatment is done to achieve the required properties on the fabric surface after deposition. In this process, the washed nickel-plated fabrics were exposed at 150˚C for 1min. After electroless nickel plating, the material samples had been conditioned @ 65% ± 2% RH and 21°C ± 1°C for as a minimum 24 hours previous to in addition evaluation.

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I. Test Methods

a. Weight Add-on%

The fabric weight, before and after the electroless nickel coating method, was measured by using the electronic balance as ‘Wo’ and ‘W’ and the % change of cloth weight was calculated by Equation

$$\text{Weight Add-on (\%)} = \frac{W - Wo}{Wo} \times 100\% \quad (2)$$

Where:

W = weight of the cloth after treatment (g);

Wo = initial weight of the cloth (g)

Scanning Electron Microscope (SEM) Analysis:

SEM - Scanning Electron Microscope investigate the external morphology of the test samples by the different magnifications to conform the nickel disposition.

b. Colour Fastness assessment

Colour fastness to washing test carried out by IS: 3417:79 standards. Light fastness of the treated fabric evaluated by ISO 105-A02:1993 method. Colour fastness to rubbing test carried out as per ISO 105-X12 standards.

c. Thermal Properties

Thermal Conductivity and resistance of the samples is measured by using Lee’s disc apparatus. Thermal resistance is the reciprocal of thermal conductivity.

d. Result And Discussion

The nickel deposition (weight add on %) on spun bond polypropylene non-woven for 15 samples are given in Table .2.

Sample number	Temperature (°C)	Time (min)	pH	Weight Add on %
1	60	45	8	19.77
2	60	45	10	30.15
3	40	45	9	3.98
4	40	30	8	2.50
5	80	45	9	1.76
6	80	30	10	1.04
7	60	30	9	10.20
8	60	15	10	8.00
9	60	30	8	4.50
10	40	15	9	1.00
11	60	15	9	0.70
12	60	45	9	0.25
13	40	30	10	2.00
14	80	15	9	1.66
15	80	30	8	1.25

Table.2 Experimental results of weigh add on %

Regression equations developed to study the influence of nickel deposition process variables such as temperature, duration and pH on weight add on percentage of spun bond polypropylene non-woven fabric. The regression equation showed that the weight add on percentage of samples were extremely influenced by all the processing variables of the nickel deposition process. The R2 value obtained was 99.3%.

$$Y=-152.400+2.049X_1+0.704X_2+19.985X_3-0.017(X_1*X_1)-0.003(X_2*X_2)-1.059(X_3*X_3)-0.002(X_1*X_2)-0.004(X_1*X_3)\ 0.038(X_2*X_3) \quad (3)$$

e. Study of Process Conditionfor Weight Add-on%

Nickel deposition depends on Temperature, duration and pH in the deposition process. These three parameters individually or by combination determine the nickel deposition. The influence of the above variables on Weight Add-on % are investigated with the help of contour plots.

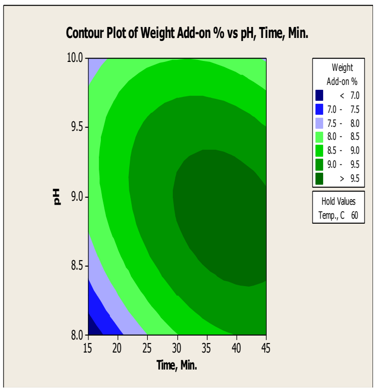

Figure.1 Contour plots of Weight Add-on% with respect to time and pH

f. Influence of Time and pH on Weight Add-on %

The graph (Figure.1) shows the dependence of duration and pH on Weight Add on percentage. As duration and pH increases the weight add on percentage increases gradually and maximum weight add on > 9.5% was observed at 30 to 45min and 8.5 to 9 pH. After 45 min and 9 pH the weight add on % tends to decrease. It suggests that nickel adhesion may not be advanced further via extending the deposition pH subsequently its saturation, and the optimized pH for nickel deposition is 9. Both time and pH has the significant impact on weight add on % when the hold on value of temperature kept at 60° C.

g. Influence of Temperature and pH on Weight Add-on%

The graph (Figure.2) shows the dependence of temperature and pH on Weight Change %. As the temperature increases the weight add on % increases steadily and reaches the maximum weight add on > 8 % at the range of 55 to 65° C and at minimum pH 8. After 65° C the weight add on % decreases gradually. Furthermore, the operation under the encouraged variety yields unsuccessful deposition result as well as gradual plating rate. It can additionally reason for low adhesion and plating due to low initiation. Primarily based at the experimental outcomes, the optimized temperature decided for nickel deposition is established to be 60°C.The temperature has the significant impact on weight add on % compared to the pH.

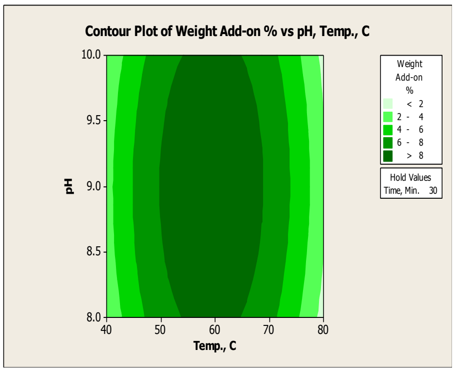

Figure.2 Contour plots of Weight Add-on% with respect to temp and pH

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Influence of Temperature and Time on Weight Add-on%:

The graph (Figure.3) shows dependence of temperature and time on Weight add on %. As the temperature increases the weight add on % increases steadily and reaches the maximum weight add on > 8 % at the range of 55 to 65° C and at minimum time 15 min. After 65° C the weight add on % decreases gradually. It confirmations that nickel adhesion may not be stepped forward additional via extending the deposition duration subsequently its saturation, and the optimized time is for nickel particles deposition is 30 minutes. The temperature has the significant impact on weight add on % compared to the time.

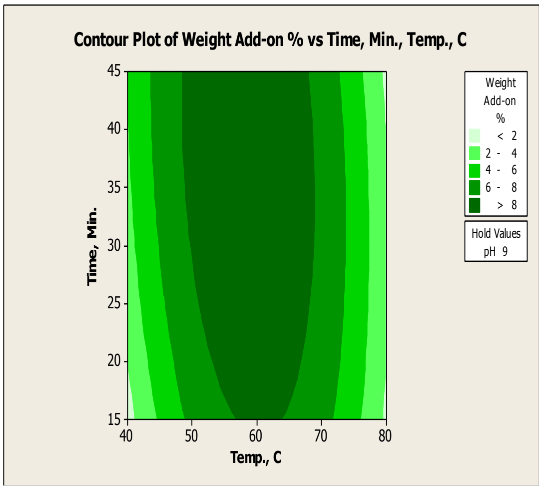

Figure.3 Contour plots of Weight Add-on% with respect to temp and time

h. Response Optimization

Through the of Minitab 15 software the response optimization was found out and from the Figure.4. It can be noted that the moderate temperature, time and pH contributing to the increase in the deposition of nickel particle. To achieve the maximum values from the available samples the global solution would be of Temperature (°C) = 60, Time = 30 min and pH= 9.

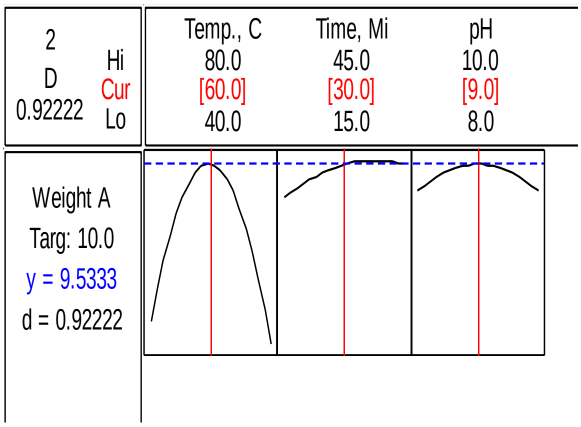

Figure.4. Response Optimization

i. Optimized sample characterization

The Table.3 shows the thermal and color fastness properties of nickel coated spun bond polypropylene nonwoven fabric produced at optimized conditions of nickel deposition process.

Characteristics	Values
Thermal Properties	
Thermal Conductivity	70 W/mK
Thermal Resistance	0.014 k.m/W
Colour fastness Properties	
Colour fastness to Light	4
Colour fastness to washing	4
Colour fastness to Rubbing	1-2

Table.3 Thermal, Electrical and colour fastness properties of sample manufactured at optimized conditions

The thermal conductivity of the sample produced from the optimum conditions shows the better values of 70 W/mK and the thermal resistivity is 0.014 k.m/W respectively. The colour fastness to light and washing shows the better result of 4 rating. However, the colour fastness to crocking shows a poor rating of 1-2.

j. Scanning Electron Microscope (SEM) Investigation

The SEM Image of the nickel plated fabrics in different magnifications are as follows which confirms the presence and uniform deposition of nickel on the material surface for the sample produced at optimum condition. The figures 5&6 show the SEM photos of samples measured in 200,300,400 and 750 magnifications respectively.

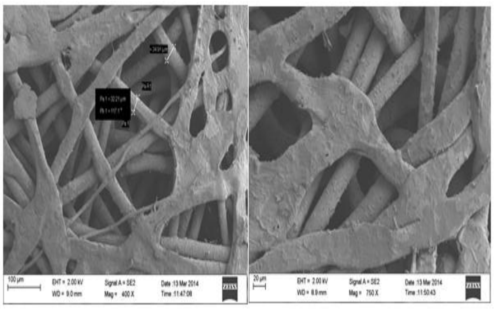

Figure.5 SEM micrographs of optimised nickel-plated spun bond PP fabric
(a) 400X and (b) 750X

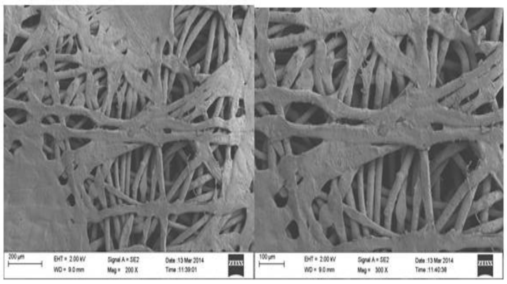

Figure.6 SEM Micrographs OfOptimised Nickel-Plated Spun Bond PP Fabric
(A) 200X And (B) 300X

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All figures.5 & 6 clearly illustrate that the surfaces of nickel-plated spun bond polypropylene nonwoven fabric are enclosed by nickel elements. The nickel elements deposited uniformly dispersed throughout the strands on the optimised nickel-plated fabric are more. The next significant point is the size of nickel elements deposited on the optimised nickel-plated strands that of is nearly alike to each other. The general results show that the optimisedelectroless nickel coatings adequate and effective to increase the performance of nickel bonding on spun bond polypropylene nonwoven fabric.

III. CONCLUSION

In this paper, the optimisation of electroless nickel coating on spun bond polypropylene nonwoven fabric is investigated through the box and behnken method. It was found that the deposition stage of the electroless nickel plating process with the parameters of temperature = 60ºC, time = 30 minutes and pH = 9 is the ultimate technique in enhancing the nickel deposition performance. The optimised deposition form had a visible enhancement in the nickel elements spreading. The nickel elements were more homogenously spread on the optimised spun bond electroless nickel-plated polypropylene nonwoven fabric as confirmed by the SEM analysis. The thermal properties and colour fastness to light and washing shows that the fabric properties improve with the increase in the volume of nickel elements observed on the optimised nickel-plated materials efficiently. Though, the enhancement of the performance of nickel element deposition caused in the weakening of the properties of colour fastness to rubbing.

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